

CONTROLLER ACCEPTANCE OF NEW AIR TRAFFIC CONTROL (ATC) AUTOMATION

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Introduction

With rapid growth in air traffic, the Federal Aviation Administration (FAA) has been under considerable pressure to increase the capacity of the National Airspace System. One of the FAA's solutions is to provide air traffic controllers with automation tools designed to increase their efficiency. Using experience with the Free Flight Program as a case study, this paper explores some of the challenges and successes with implementing new air traffic control automation tools.

This is an attempt to take a hard look at what kinds of automation that people, specifically Air Traffic Controllers, find helpful and will readily accept compared with automation that they do not accept. I believe that gaining an understanding of this is critical to success when designing and planning the implementation of new air traffic control automation systems.

As we move forward toward more automation in the air traffic control system, a comparison is made with the interesting history of automating the duties of the street traffic cop in our cities. Although controlling traffic in the air and on the ground are far apart technologically, many of the issues in moving from a human-centered to a machine-centered system are worthy of comparison. This helps provide insights into acceptance of automation both by the controllers and those being controlled.

The Free Flight Program (FFP) includes several initiatives for modernizing the National Airspace System. Three of these initiatives or "tools" that are included in phase one of the Free Flight Program are decision aid tools for controllers.

These tools include:

- **User Request Evaluation Tool (URET)** — Provides conflict detection

up to 20 minutes in advance for each aircraft and predictive capability to determine conflicts that would result from proposed routing or altitude changes. URET also provides automated flight data processing and automated input of flight plan amendments. URET displays information using a separate display from the controllers' primary radar display.

- **Traffic Management Advisor (TMA)** — Provides information to the controller on how much an individual aircraft must be delayed in order to maintain an even and equitable flow of aircraft into terminal areas without exceeding a maximum rate. TMA displays information to the controller in the form of a list, not as part of the data block, on the controllers' radar display.
- **passive Final Approach Spacing Tool (pFAST)** — Suggests a runway assignment for each arriving aircraft and an arrival sequence to balance the flow of aircraft to multiple arrival runways. This helps maximize the throughput of aircraft at an airport. The pFast tool displays runway assignment information within the data-block associated with arriving aircraft on the radar display.

Controller use of all three of these tools has been shown to deliver quantitative benefits to airspace users in the form of increased airport throughput and/or decreased flying time or distance. As of June 2002, the Free Flight Program successfully fielded two of these tools at several FAA Air Traffic facilities. The fielding of pFAST stopped when it was determined the technology was not yet mature enough for continued deployment. At least part of this determination was made based on controller input.

The three FFP tools previously mentioned are all decision aids but differ significantly in the type of information provided and use different means of displaying information. As noted above, the display methods range from a separate display to a list on the controllers' primary display, or radarscope, to inclusion in the data-block associated with each aircraft. My observation is that the further the automation tool goes towards appearing to have actually made a *decision* for the controller, the higher the level of controller critique of the tool. Of the three tools, pFAST goes the furthest in actually making a decision for a controller by presenting runway assignment information as a decision made by the automation. The controller can choose to accept the decision provided or reject it without the benefit of knowing what factors were considered in making the decision.

URET, on the other hand, simply highlights potential problems, facilitates exploration of options, simplifies the process of inputting route changes, and automates the tracking of flight data. While URET has extremely complex software and has had its share of issues with controllers, the fact that it works strictly as a decision aid and streamlines controller inputs has made it well accepted by controllers.

Future upgrades to URET include recommendation(s) of route amendments to best mitigate a conflict or provide a more direct route. It seems likely that, as URET begins to recommend solutions, controllers will increase critique of the decision algorithms.

Also, one of the future upgrades to TMA being considered includes changing the presentation of information from the current list to become part of the data-block. Even though controllers have recommended this change, this too, may increase critique of the information provided, as the list context is lost.

Controller critique is an integral part of developing a safe and efficient system. I will attempt to highlight the importance of making early determination of whether new automation is intended to aid human decisions or replace human actions.

In an environment as complex as the air traffic control system, the potential of *fully* automating controller instructions is heavily debated. Although not the primary focus of this paper I will attempt to shed light on a potential means to transition to more automation in the ATC system.

Background

First, I am *not* a Human Factors Specialist. I am an Air Traffic Control Specialist with over twenty years of field experience several years of which I was a supervisor. During this time I have had the opportunity to provide instruction to many other controllers in order to help them learn how to control effectively.

I have also experienced Air Traffic Control services from the user perspective as an instrument rated pilot and have provided flight instruction and instrument instruction to others.

Finally, automation has long been an interest having spent many hours working with computers as a hobbyist since the very early days of personal computers and have used this experience within FAA.

This has given me many opportunities to observe, and experience for myself, the interactions of people with the variety of equipment used in aviation, including interactions with new equipment or systems. I am very much interested in seeing automation improve the Air Traffic Control system and can envision a time the system looks and operates significantly different, and better, than it does today. The transition, I imagine, will be long and difficult.

It is from this perspective that the following observations and ideas are presented.

Early Street Traffic Control

As we explore the introduction of automation into ATC tasks, let's use an example that, admittedly, is a very simple one but seems to have many parallels with modernizing air traffic control. Let's explore the tasks of the old fashioned Traffic Cop. You know, the person that stood out in the middle of a busy city intersection and "controlled traffic". Although controlling street traffic is not as

complicated as controlling airplanes; it still involves a person taking in available information and using this information to make decisions in order to efficiently control traffic.

We all know that this task has been almost entirely replaced by automation—traffic lights. How did this system evolve into the near fully automated one we see today? In searching for the answer to this question, I found the book *TRAFFIC DEVICES: Historical Aspects Thereof* by Gordon M. Sessions¹ was found to be a thorough study of the history of traffic signals.

First, according to Sessions, the transition occurred over many years with many different technologies attempted. The first known police regulation of traffic in the United States began in 1860 in New York City while automated signals began gaining widespread acceptance in the late 1920s.

Also, the proliferation of automobiles produced considerable pressure on the government regarding traffic control. “It was ... in 1927 when Paul W. Brown, editor of *Executive’s Magazine* (St. Louis), solemnly predicted that 30 million motor vehicles would be the ‘saturation point’ in the United States, and that this point would be reached in 1934.”¹ This sounds remarkably like recent predictions of soon to come saturation or “gridlock” of the nation’s skies.

Importance of Information and Communication

As our traffic cop did his job, he took in the available information, and used this information and his judgment to make decisions on which traffic should be held, or delayed, and which traffic should be allowed to proceed. He observed the amount of traffic coming from the various directions, the type of traffic, the speeds and so on, and used this information to make a decision. He then communicated the decision to the traffic. The traffic officer welcomed additional information in order to help him make better decisions. He wanted to know what was over the hill or around the corner, beyond what he could see.

To augment his available information in order to improve his decision-making, several strategies were used. One common strategy was to simply

provide an elevated platform so that the officer could see further. This also made it easier for the traffic to see him, which facilitated better communication. As early as 1917, communications began between officers at multiple intersections so they could coordinate traffic movement to improve efficiency.

Numerous devices were also used to facilitate the communication of the decisions to the traffic. Semaphores were common at first, then lights were added to the semaphores, and finally lights prevailed. These early signals were still controlled by police officers however.

In comparison, the idea of providing our traffic cop with *automated decisions*, while possible, would probably not have been readily accepted. Can you imagine that a traffic cop would have welcomed a timer telling him when he should switch traffic flows? Imagine him being expected to hold traffic while waiting on the timer when there were clear opportunities for the traffic to go. He would have seen the timer as inefficient and incapable of making decisions as effectively as he could make them—the timer lacked good judgment given the real time complexity of traffic flows.

In fact, early attempts at automating traffic control met considerable resistance. Burton W. Marsh, the first professional traffic engineer to be employed by a city full-time (Pittsburgh, 1924) commented about competent traffic officers saying: “In brief, while working at his best he can use brain power for the best handling of traffic ... and brain power efficiently used is, of course, usually better than mechanical control for a single corner.”¹ Another example, J. W. A. “Arch” Bollong, a long time traffic engineer at Seattle, once wrote: “In 1924, various types of signals were on the market. All extolled their virtues, with the result that one signal ... was erected at 2nd Ave. South and Jackson St. The police officer located at this intersection refuse to work with the darned thing.”¹

Application to Air Traffic Control

Like our traffic cop, air traffic controllers will welcome additional information that will help them make better decisions. They will be less

likely to accept decisions made by automation. This is especially true if they do not have the information that went into the automated decision and even more importantly if they see some of the automated decisions as wrong or less than the best.

Transition to Automation

In spite of the resistance to the automation of street traffic control, there were numerous attempts to automate with many of these attempts being very short lived because, even though they seemed like good ideas, in practice they were unworkable. However, we all know that ultimately, timed lights replaced the traffic officer's decisions. Of course, traffic light controls have now become very sophisticated working as a system yet, at times, we still wait for the light when we could obviously go safely. This leaves one wondering how and why did the change take place?

First, it appears that this was a cost versus benefit decision. That is, the cost of the traffic cop was seen as greater than the cost of the efficiency loss when replacing him with a timed light. Marsh wrote of this "... the staggering cost burden of continually adding traffic officers ... to take care of the fast-increasing number of corners demanding 'stop-and-go control.'" An excerpt from a 1928, paper by C. A. B. Halvorson, General Electric designing engineer says: "... by the end of the year there will be in New York City alone 3,000 intersections controlled at an initial cost of \$1,000,000. This would have required 6,000 policemen at an expense of \$15,000,000 to accomplish similar results."

An indication that at least some concern that the cost of lost efficiency might be too great when replacing officers is indicated in this comment by William P. Eno who was internationally known in the field of traffic control: "Students of traffic are beginning to realize the false economy of mechanically controlled traffic, and hand work by trained officers will again prevail."¹

How did the change to traffic lights occur? The timed signal simply replaced the traffic officer when it was put in use. There were many locations where the officer would control the signal during busy periods and then a timer would control it during less busy times. During the less busy times,

reduced efficiency had less adverse impact than would occur during the busier times. Also, the officer was not expected to use a timer (automation).

Once the concept was refined and accepted, timed signals were installed at the busier intersections replacing the officer. Many combinations of lights had been tried prior to settling on the three colors we now use with the yellow only shown to the moving traffic.

Four points worth considering here are:

1. The human was not expected to use the decisions made by the new technology.
2. Initial testing of new technology meant to replace human decisions is best done at less busy locations or less busy times.
3. Maximum efficiency is not necessarily required
4. Sometimes attempts to use new technology end in failure.

Human Factors in Automating ATC

Now let us continue to look at the parallels with air traffic control. First, let me say that I do not believe that the air traffic controller is likely to be replaced anytime soon. There are some, maybe most, people that envision a time when air traffic control will be near fully automated. It seems like that time is still a long way off. Automation is not yet able to provide safe control of aircraft at a level of efficiency that would be acceptable. Unlike the automobiles of our example, aircraft are very fast, cannot stop, and operate in three dimensions, all of which add to the complexity of the problem by very large factors. Also, in the aviation industry, small changes in efficiency amount to large sums of money.

With today's level of sophistication, we find that automation it is very good at some things. Generally, automation is good at monitoring and good at repetitive simple tasks. According to FAA report *Human Factors in the Design and Evaluation of Air Traffic Control Systems*: "people are notoriously poor monitors."² We have numerous monitor panels that tell us when something is wrong with our equipment. We have

the Automatic Terminal Information System (ATIS), an early form of ATC automation, that endlessly repeats a broadcast of information to those that need it relieving the controller from repeating it to every aircraft. Within the FFP1 program, and much more sophisticated than the two previous examples, is URET, a tool that checks and monitors traffic for conflicts and processes flight data. People readily accept being replaced by or giving up tasks to automation for these kinds of duties.

Where automation is less capable, with today's level of sophistication, is in processing information from many sources with many variations and making good decisions. "People are flexible information processors who are sensitive to changing conditions and situations. They are resourceful in using both quantitative and qualitative information and in integrating information received from various sources. It is these unique information-processing abilities, honed by training and experience, that make the controller an invaluable component of the ATC system."²

An example of this is the sequencing of aircraft to an airport, the function which pFAST is designed to help. People are better able to make the decisions that require good judgment than automation, and the controllers can readily see that this is so. Where controllers will say that pFAST may help, is that it provides them with additional information that an individual may not otherwise have. An example we often hear concerns gaps in the sequence numbers provided by pFAST; these gaps indicate that there is other traffic somewhere to fill the gap. This additional information is useful.

The pFAST tool helps to balance the flow of aircraft to multiple arrival runways in order to avoid missed landing opportunities on one runway while aircraft are delayed on a long final approach to another. It has complex algorithms that processes information from several sources and presents the "decision" as a suggested runway assignment on the radar display.

I believe that if pFAST had been designed to present information in another way, it may have been seen as a decision-aid and controller acceptance might have been high. As an example,

if a controller is working a feeder sector and is trying to determine the best runway assignment for an aircraft entering his/her sector, it would be helpful if there were a list showing how many aircraft are already assigned to the various runways. The controller's decision would probably be to assign the aircraft to one of the less busy runways, which would help balance the flow. However, there might be a very good reason to do something different. In any case, there is no pre-established *decision* to either accept or overrule.

Certainly, when striving to provide controllers with additional information, care must be taken to avoid overwhelming the controller with information. Here is an excerpt from *Flight to the Future Human Factors in Air Traffic Control* published by the National Research Council: "Humans can absorb and make use of only very limited quantities of information. It is well established that displaying all the information that might be useful means there is too much information to be able to find what is needed when it is needed. The control panel at the nuclear power plant at Three Mile Island and the Boeing 707 cockpit are early examples of this problem."³

The challenge then, is to determine what information is truly useful without being overwhelming to controller. It seems that runway usage information is useful to a controller that is making a decision regarding runway assignment while it would not be useful to others.

Trusting Automation

Earlier mentioned was the problem of a person being presented with questionable or clearly wrong information even at a small level. This creates a lack of trust in the information provided and causes a person to tend to discount all of the information provided by the system. "Automation that is unreliable is unlikely to be trusted by the operator and therefore will not be used..."³ This seems to be especially true with air traffic controllers and the radar displays the data they use is presented on.

For many years now, radar displays have been used as the primary system for controllers to use when providing for aviation safety by separating aircraft in flight. This, being critical, has caused

controllers to have an expectation the information on the radar display is always exactly right. It seems that even when suggested information is presented to the controller on the radar display, if it is not right then the controllers are more likely to reject it and reject the tool that provides it.

Job Satisfaction

I believe that controller job satisfaction is also a factor in controller acceptance. Probably a much larger factor than is usually known. In my own experience I have felt significant satisfaction in running a good arrival sequence and a good efficient final. While I have not used it, my own initial reaction when I first learned about the operation of pFAST was that I did not think I would like it.

The following also speaks to this:
“Acceptance ... depends on the impact that new ATC technology has on controller job satisfaction. It may be the case that sources of job satisfaction in the current system are disrupted or removed by the new technology.”²

Again, where pFAST is concerned, we often heard controllers express concern that the automation was not as capable as it needed to be. We often heard comments to the affect that pFAST sequencing was “not the way controllers would do it.” It may be though, that the people were actually feeling that, perhaps subconsciously, their high level of job satisfaction was in jeopardy. If some of these feelings existed during the use of pFAST, it is likely that the controllers would not have expressed them. Instead they would be more likely to find fault with the new system. Even if a degradation of job satisfaction did surface, there would have been a feeling that the decision makers would probably not determine it would be a sufficient reason to avoid deploying a technology that otherwise provided benefit to NAS system users.

Adapting Automation to Humans

An observation that seems to bear out some of these ideas presented here is a pFAST installation at Southern California TRACON (SCT). The system was installed for the purpose of helping controllers with the Los Angeles (LAX) arrivals.

Due to some unusual conditions within the LAX and surrounding airspace, there were a number of situations where it became apparent that pFAST would not properly make runway allocations without significant adjustments to the algorithms. The controllers involved in making this determination did, however; discover that there was useful information in pFAST that could be used without the automated decision. This resulted in a “molding” of the system to make this information available to the controllers on separate displays. These auxiliary displays support controller decision making by “letting him know what is around the corner”.

Another observation though, is that molding of a system by its users does not necessarily ensure that other users will accept the system. Again in the case of pFAST, I have been told that during development, there was considerable controller input on the computer-human interface. Some have expressed that the interface was actually designed by the controllers.

These controllers were a ‘cadre’ of a few controllers that were heavily involved in the development of the prototype pFAST system. They were providing input trying to adapt the prototype system into a usable format. They necessarily had considerable knowledge of the algorithms within pFAST and the goals that were trying to be achieved. An important point here is that they understood the bigger picture of what the automation was trying to achieve and were anxious to realize the benefits of it.

This leads one to wonder why would a group of people help design an interface that their peers would not ultimately accept. I can only speculate here however, I would imagine that it was an evolutionary process. One factor that might have influenced this evolutionary process is a perception among many that separate lists of information should be avoided so that the amount of time attention is diverted away from the traffic being worked is minimized. This would have left the data block associated with each aircraft on the display as the logical place to display the information. However, in this scenario, only the information for the one aircraft would be displayed in its data block. Because the runway assignment is normally a controller decision, insertion of the

‘suggested’ runway by pFAST appeared as a decision already made.

If the pFAST designers had decided early that presentation of information as a decision already made was to be avoided, perhaps it might have evolved a different way. Admittedly, this is easy to speculate in hindsight, however; it might be worth considering in the future.

Adapting Humans to Automation

TMA seems to fall somewhere between URET and pFAST as far as controller acceptance is concerned. Since TMA presents a delay advisory in time, those facilities that are accustomed to time based metering seem to readily accept the information unless it is clearly wrong.

Where we get some resistance to the use of TMA is from facilities that are not accustomed to time based metering. At these locations metering is normally accomplished by adjusting the miles-in-trail for all of the aircraft on each of the various arrival routes entering the TRACON airspace. To make use of the information provided by TMA, requires them to change the way they are working in order to accommodate the tool.

As always, people are resistant to change and arguably, miles in trail metering is easier for a controller to apply than time based metering. Also, arguably, time based metering is a better form of metering to minimize and appropriately distribute needed system delay. I believe that if a change in the method of work is appropriate, care needs to be taken to separate the need for the change from the implementation of a tool. Otherwise, the implementation of the tool will be perceived as the reason for the change, which will create an unwillingness to accept the tool.

As this is being written, early indications are that the appropriate level of care has been taken for transitioning to time-base-metering at Los Angeles Center (ZLA). A time-based-metering test is currently underway there using TMA and feedback is very positive. A cadre team of controllers was trained on the use of TMA including simulation training. This allowed the team to see the potential benefit of the system while learning that the adjustments needed in their work methods were reasonable. This simulation training also included

some TRACON controllers allowing them to see the benefits of TMA and giving them confidence that the operational change would not create problems for them.

Phasing in Automation

Another point to consider when thinking of our traffic cop analogy is the spiral development concept. Spiral development has been embraced as a means of modernizing without overwhelming the people working in the current system with too many changes at once. That is, we make small incremental changes, building slowly toward a more modern system.

As mentioned earlier, it does not seem like too much of a stretch to assume that some day automation will be sophisticated enough to replace most of the decision making now done by Air Traffic Controllers. However, I do not think that taking decision-making away from the controller while leaving him with other tasks is a candidate for spiral development. Again, our traffic cop would not have accepted a first step of using a timer to decide when to switch traffic flows. When the automation does get sophisticated enough, we will, I imagine, use it at low activity locations or during low activity periods first. Early automated systems will probably not be as efficient as they could be with further development, so minimizing efficiency loss will be important. We will test, adjust, ensure safety is not compromised, and improve efficiency before using for busier traffic. Once proven, the automation will simply replace the controllers at even the busiest times. At this point, there still will likely be a small loss of efficiency when the replacement occurs.

Spiral development is good for providing additional information to controllers or for automating the simple tasks. Controller Pilot Data Link Communications (CPDLC) is a good example of potential here. I believe controllers will welcome the reduction of repetitive communications they now endure as long as the interface is easy to use. With rapid advances in modern technology making many possibilities for providing additional information to controllers or relieving them of simple tasks, spiral development prevents them from being overwhelmed with too much change at once.

When considering the deployment of new technology, I believe we need to make an early determination of whether the technology is intended to make decisions or not. If it is a decision maker, job satisfaction is likely to suffer and controller acceptance will be difficult to obtain. The path toward successful deployment will significantly differ in each situation.

In the case of pFAST, or the next generation, aFAST (active final approach spacing tool) that along with suggesting runway assignments also “suggests” headings and altitudes, controller acceptance is not likely. Successful deployment of FAST technology without a controller in the loop will need to wait until other technologies are mature. For example, there will still need to be a way to communicate the instructions associated with the decision to the aircraft. With plans to deploy data-link already under way, it is conceivable that this can be done in the future.

Conclusions

In developing new tools to help people do their jobs in ATC, we need to consider a few key points:

People will readily accept:

- Additional information allowing them to make better decisions
- Reduction in monitoring tasks
- Reduction of simple repetitive tasks

People will not readily accept:

- Decisions being made for them
- Additional workload to facilitate technology
- Overwhelming changes

When technology is ready to displace human decisions, it needs to be first implemented at low activity locations or times where there is no competition with people then, as it matures, replace the people. It cannot gradually replace human judgment while the human is still in the loop. Successful deployment of new technology requires early determination of whether it needs to be accepted by people or replaces their decisions and proceeding accordingly.

As a final note, I believe that the automated traffic control of our streets, using traffic lights, has now surpassed what could have been done with individual human traffic cops working intersections. We now have sophisticated systems, with minimal (but some) human interaction, sensing traffic levels and adjusting timing of a multitude of traffic lights in order to move traffic efficiently. And, when warranted by unusual conditions, we still revert to the human traffic cop. Probably, some day; we will be able to say the same things about air traffic control.

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